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ABSTRACT

A study examined the effects of implicitly embedding short passages explicating information (etymological, analogical, or causal) within a given text on the learning of verbal information. Instructional materials were developed which used two different sequences, one control group receiving filler materials, and three groups receiving one of the different types of explication. A total of 184 undergraduates enrolled in programs in a college of education read text organized into one of two instructional units on the human heart and completed a series of four tests (drawing, identification, terminology, and comprehension) two days later. Results indicated that: (1) treatment groups performed better than the control groups that received filler material on the measures of cued recall and recognition; (2) the analogical and causal treatment group mean scores were significantly higher than the control group mean scores on a drawing test; and (3) students receiving the vocabulary-last sequence performed significantly better than the students receiving the vocabulary-first sequence on drawing and terminology tests. (Contains 26 references.) (RS)

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EXPLICATING BIOLOGY VOCABULARY WITH ETYMOLOGIES

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Explicating Biology Vocabulary with Etymologies

Background

The ability to read and understand text is vital for learning and remembering information. Experts have suggested that learners typically have more difficulty reading expository than narrative text (Spiro & Taylor, 1980). Readers may lack prior knowledge or experience (E. Gagne, 1985). Another possibility is that readers do not learn prerequisite information needed to understand new information (R. Gagne, Briggs, & Wager, 1988). A lack of motivation and interest may result in less time spent on reading outside of school and thus less experience with reading expository as well as narrative text (R. Anderson, Wilson, & Fielding, 1988).

Informative text that facilitates understanding, learning, and remembering uses certain text characteristics that facilitate learning from written materials. Standard characteristics of expository text include structure, coherence, unity, and audience appropriateness (Armbruster & T. Anderson, 1984). The evaluation of various social studies and science text segments sometimes reveals a deficiency in those properties (T. Anderson, Armbruster, & Kantor, 1980).

However, even texts that include those characteristics may lack features that enhance comprehension. Those features include text organization schemes, explication of information by familiar examples, causal relations, vocabulary usage, analogy, and various instructional devices (Singer & Donlan, 1989). Reading material should enhance a potential relationship between the student's schema and the information to be learned.

Explication of Information

To explicate means to state directly, instead of requiring the reader to infer, organize, or construct relationships (Singer & Donlan, 1989). Learning will occur if the text directly explains the terminology or causal relations (Bean, Singer, Sorter, & Frazee, 1987). Systematic surveys indicate that information is directly explicated in elementary textbooks (Dreher, Singer, & Letteer, 1987; Letteer & Singer, 1985). However, high school texts typically are not explicated. Because experts do not agree on the role of causal relations, these texts do not explain causal relations (Fitzgerald, 1979). Systematic surveys of college textbooks are scant. Thus, explication of information should be a concern for instructional designers.

Explication by Etymology in Text. The usual practice in textbook writing is to define new terms as they occur. This is consistent with the role of prerequisite information in learning (R. Gagne et al., 1985). However, the definition provided should bridge the gap between new and prior knowledge. Because new vocabulary words are required for understanding subsequent text, the reader may lack the knowledge structure needed to subsume the concepts underlying the new terms (Ausubel, 1968). This presents a cycle which must be broken so that meaningful learning occurs.

Word etymologies are concerned with the origins and derivations of a word. Medical terminology is derived from about 4,000 Greek and Latin terms that form various prefixes, suffixes, and roots (Pepper, 1949). Familiarity with those Greek and Latin terms and an understanding of their use would save a student from memorizing more than 50,000 words. Understanding relevant Greek and Latin meanings and their usage as prefixes, suffixes, and roots should facilitate processing for acquisition of knowledge and word identification.

Providing the reader with explanations about word etymologies and derivations should enhance selective attention and acquisition. The passage containing the etymology would draw the reader's attention to the word. Acquisition may be enhanced by linking information learned from the text with the word etymology. If there is anything familiar to the reader within the etymology, a prefix such as peri- for example, this would integrate prior knowledge in long-term memory with the etymological information. This should enhance retrieval processes.

Explication of Causal Relations in Text. Causality is an action that regularly produces an effect, it means that there is a predictable or functional relationship between a cause and its effect (Schlick, 1949). This should link one new term with another as it is encountered in the text. DeKleer & Brown (1983) state:

> The causal model describes the functioning of the device, i.e., a description of how the device's behavior results from its constituent components which is stated in terms of how the components causally interact. (p. 158)

This linkage would organize the information and thus affect recall of simple arrangements and relationships (Mayer, 1988; Mayer & Bromage, 1980). Thus, in terms of Mayer and Greeno's (1972) model, explicating causal relations should enhance constructive processes. Retrieval processes may be enhanced as a result of linkages among knowledge from the text.

Explication by Analogy. The essence of analogical thinking is the transfer of knowledge from one situation to another by finding correspondence between the aspects of two different bodies of information (Gick & Holyoak, 1983). Analogies can aid learning by comparing abstract concepts with concrete (Newby & Stepick, 1987). Rumelhart and Ortony (1977) and Norman (1978) discussed analogical schema existing as formal structures that could be supplemented with new information. Where prior knowledge exists, an analogy can bridge the gap between the familiar and the unfamiliar by providing anchors for assimilation. The analogy conveys overlap in relations among objects, but no particular overlap in the characteristics themselves (Gentner & Gentner, 1983). In addition, a literal analogy may show commonality between two objects in both function and description.

Explication by analogy should enhance integration of new information with familiar knowledge in long-term memory. The presentation of analogies incorporates the main conceptual ideas

and relations into a structure that will facilitate the assimilation of new information (Mayer & Bromage, 1980). This should improve both encoding and retrieval processes.

Summary of Methodologies

To test the hypotheses, instructional materials were developed which used two different sequences, one control group receiving filler material, and three groups receiving different types of explication resulting in a 2 (sequence) X 4 (embedded explications) factorial design.

Subjects. A total of 184 undergraduates, enrolled in programs in a college of education, chose to participate in the study. All students completed a test delayed by 48 hours. Subjects were asked to report biology courses they had taken. If subjects reported taking 15 or more credits in biology which included extensive human anatomy and physiology, they were excluded from the study.

Materials. The instructional content developed by Dwyer (1965) consisted of an 1,800 word instructional unit describing the parts of the human heart, the internal functions of those parts and the interrelated functioning of the heart. With the addition of explication passages, the instructional unit was expanded to 2,100 words.

Three types of explication were written by the investigator. Their content was based upon the investigator's study of mammalian anatomy and physiology and dissection experience. The explications were all located within the section discussing new terminology: The Heart and its Functions. This section was presented first to half of the subjects and last to the remaining half. Each explication passage consisted of approximately the same number of words and was located at precisely the same point in the parallel texts. With the exception of the filler material, all explications described the same terms. The filler material did not refer to the functions or parts of the heart.

Filler Material. Filler material was added to the control group scripts in order to provide equivalent reading material with the same number of words. The filler material was historical in nature and discussed the study of heart transplantation through the development of the artificial heart. For example, two fillers were as follows:

> For the past twenty years or so doctors and surgeons have been studying the techniques of the transplanting of the human heart.
>
> Teams of surgeons at medical centers in scores of cities around the globe worked together to attempt the first transplant of a heart from one human being to another.

Explications. Each script contained one set of twelve explication passages that were etymological, causal, or analogical. They were placed at precisely the same points in all scripts. The Vocabulary-First Sequence presented the section

containing explication first while Vocabulary-Last Sequence presented the section last.

Etymological explications discussed the same terms as other explications. Information regarding the naming of the part of the heart or the meaning of prefixes and suffixes was stated within approximately the same number of words as the fillers and other explications. For example, the following elaboration discusses the meaning of prefixes and suffixes in pericardium:

> The word, PERICARDIUM can be broken down into two parts: PERI- and -CARDIUM. The root, CARDIUM comes from the Latin word for HEART while PERI comes from a Greek term meaning "around the outside".

Not all of the terminology associated with the heart was derived by combining prefixes and suffixes. Some terms were named, accurately or inaccurately, for their functions. For example, the aorta was named for its inaccurately perceived function:

> AORTA is derived from the Greek AEIREIN, a passive form meaning to be hung". It was believed that the heart hung from the artery.

The effectiveness of these types of etymologies can be determined by multiple comparisons of the means and an item analysis of the definition portion of the test.

These forms of explication were approximately the same word count as the filler material and the other embedded passages. For example, the following statement links the function and characteristics of the pericardium to the term covered next in the script, the epicardium:

> The pericardium must be tough enough to protect the heart yet flexible to expand and contract. If it were damaged in some way, the epicardium would become shredded.

This can be broken down into the function

> The pericardium must be tough enough to protect the heart yet flexible to expand and contract.

and then divided into cause

> If it were damaged in some way,

and effect

> the epicardium would become shredded.

These statements were designed to show relationships between the names and functions of the parts of the heart. In this case, the epicardium is linked to the pericardium as it indeed is in the heart.

Another example of causal statements can be discussed:

> If the auricle walls were too thick and strong, the pressure of the blood flowing into the ventricles would be too high. Also the auricles would not receive an adequate

quantity of blood.

The ventricles pump the blood all the way throughout the body. If they were weak, circulation would be poor.

In this statement, the cause is hypothetical rather than realistic, although it may be possible to see similar pathological conditions. The cause for the auricle function is

If the auricle walls were too thick and strong,

and the effect is

the pressure of the blood flowing into the ventricles would be too high. Also the auricles would not receive an adequate quantity of blood.

This statement takes two factors, strength and capacity, into account.

A similar process is seen in the second half of this statement:

The ventricles pump the blood all the way throughout the body.

The cause is:

If they were weak,

and the effect is

circulation would be poor.

The effect in this instance relates back to the function of the ventricles which is to push blood either throughout the body or to the lungs, both destinations a great distance away from the heart.

One last example includes a cause and effect statement discussing the pulmonary valve which is made of three flaps in a similar fashion as the tricuspid valve:

If the three flaps were damaged in some way so that they did not close completely, some blood would flow back into the ventricle and circulation would be impaired.

Once again, this statement can be broken down into its cause:

If the three flaps were damaged in some way so that they did not close completely,

and its effect:

some blood would flow back into the ventricle and circulation would be impaired.

Again, the function of the ventricle is related to the function of the valve. If the valve does not close tightly, the blood does not flow out to its destination as it should.

Analogies were approximately the same number of words as the fillers and other explication. They, too, were located at precisely the same points in the scripts as the other explication and the fillers. Each analogy referred to the same term as the other explication. The analogies were literal whenever possible, that is, they discussed both description and function. For example, both the appearance and function of the pericardium is included in this analogy:

Plastic wrap for food, Saran Wrap or Handiwrap, is tough, transparent and elastic. It protects food. In a way,

the pericardium is like plastic wrap.

Sometimes, however, the emphasis was on function rather than precision of description. For example, in these two different but related terms, the there is no similarity in appearance between the source and the target but there is similarity of function:

The auricles are like lobbies in a hotel where people wait to go and return from their rooms.

The ventricles are like the elevators in a hotel that take people to and from the floors where their rooms are located.

The analogies were designed to activate prior, familiar knowledge and link it to the new terminology. The investigator attempted to generate meaningful, relevant analogies for the targeted subjects which consisted mostly of college students training to become teachers.

Design. The experimental design of this study was a randomized posttest-only control group design (Campbell and Stanley, 1966). The students read text organized into one of two sequences containing one of three types of explication or filler material resulting in a 2 (Explication First Sequence vs. Explication Last Sequence) X 4 (Filler vs. Etymologies vs. Causal Statements vs. Analogies) factorial design. All students completed a test delayed by 2 days.

The posttest-only design was used to prevent the possibility that a pretest would have an effect on the experimental treatment (Borg & Gall, 1989). In this study, a pretest may have functioned as an advance organizer both to activate prior knowledge about the heart and to cue subjects to attend to some information more than others. This could have interfered with both the implementation of explication and the selection of filler material. Subjects were randomly assigned to the experimental and control groups.

Dependent Measures. The eighty-item test was structured into the following sections and given in the following order: Drawing, Identification, Terminology, and Comprehension. The types of questions in each of the four tests addressed a different aspect of the heart material. The Drawing Test required the student to draw a simple line picture of the heart and place the corresponding number of the 20 identified parts listed on the test. This tested the skill level of labeling or naming (R. Gagne et al., 1988). This test offered cues for recall of structural information by listing the parts, but required the student to correctly draw and locate the part. Knowledge of the function of the part was not necessary for this test. The Identification Test required the student to select the answer that best identified the part of the heart indicated by numbered arrows located on a simple line drawing. This also tested naming or labeling skill. The Terminology Test, at the factual level, required the student to recognize the correct part of the heart, as an answer, for the function or description written in the question. The Comprehension Test, at the conceptual level, presented two functional and eighteen sequential questions that required the student to recall and apply information from

different portions of the reading material. The sequential questions presented an event in the circulation of the blood through the heart and then asked about the position or state of another part of the heart.

Procedure

Following the design of the materials and before commencement of data collection, eight volunteers were asked to read the scripts and complete the examinations. This was for the purpose of identifying appropriate time requirements, composing a presentation schedule, identifying typographical errors, and determining pacing before initiating the actual study. The volunteers were undergraduate students. Participation was on an individual basis.

On the first day, each individual received a packet with an informed consent form as a cover page, an informational page, directions, and the reading material. The investigator used the presentation schedule in Appendix D for all groups. Subjects were told that they would be tested on the reading material but that their score would not affect the grade for their course.

Subjects completed the informed consent form and the informational page under the direction of the investigator. Once these pages were completed, the directions were read aloud by the investigator. Questions were addressed at this time. Subjects were instructed to read one page at a time in numerical order, and not to look back or ahead of the page they were reading. This preserved the sequencing of the material. The arrangement of pages and the classroom seating arragement made their progress readily visible to the investigator.

The investigator told the subjects that their reading time would be limited and that they were to mark the place in the text where they stopped. The investigator did not tell them what the amount of reading time would be so that subjects would not attempt to pace themselves accordingly or become distracted by watching the time. The subjects were permitted to read each of three sections for 5 minutes resulting in a total reading time of 15 minutes. All subjects within the same sequence group were stopped at exactly the same spot in the reading.

In order to control the amount of time spent on each section that appeared at different points due to sequencing, it was necessary to break the script into three 700-word segments. The reading for each segment was timed for 5 minutes which preserved the required reading time. A page that instructed the reader to stop was inserted between sections. The investigator could easily see these pages.

On the second day of the study, two days after reading, students received the test packet including an information page consisting of identifying numbers and forms along with a computer-scanned answer sheet. Based upon the preliminary investigation and prior administration of the test, the drawing test was given for 5 minutes and the other three parts of the test were given for 10 minutes. The four tests were given in the same order to minimize possible interference effects between tests. Students

were instructed not to go back to the previous test.

In all cases, test reliabilities were satisfactory with the following KR-20 values:

Test	K-R 20	Item Type
Drawing Test	0.83	Cued Recall
Identification Test	0.81	Forced Choice
Terminology Test	0.83	Forced Choice
Comprehension Test	0.77	Forced Choice

The findings of the ANOVA of the group achievement on the drawing test resulted in significant differences among the treatment groups for both sequence and explication. There was no interaction between main effects. The F ratio for the effect of explication is significant at the $p < 0.01$ level [F (3, 176) = 3.88]. This result justifies the multiple comparison of group means in order to determine which treatment had a significant effect. Overall, the means of the groups receiving the analogical explication and the causal statements were significantly higher than the control groups that received the filler material. These group means were not significantly different from the other treatment groups, however. The findings of the analysis of treatment group achievement on the identification test resulted in no significant difference among the score variances. The findings of the ANOVA of the group achievement on the terminology test resulted in significant differences among the treatment groups only for explication. There was no interaction between main effects. The F ratio for the effect of explication is significant at the $p < 0.05$ level [F (3, 176) = 2.65]. On the comprehension test, the findings of the analysis of treatment group achievement on the comprehension test resulted in no significant difference among the score variances. A multiple comparison of means for the identification test would not be appropriate.

Summary

The purpose of this study was to examine the effects of implicitly embedding short passages explicating information on the learning of verbal information. Overall, the treatment groups performed better than the control groups that received filler material on the measures of cued recall and recognition. The analogical and causal treatment group mean scores were significantly higher than the control group mean scores on the drawing test. The students receiving the Vocabulary-Last Sequence performed significantly better than the students receiving the Vocabulary-First Sequence on the drawing and terminology tests which confirms momentum effects (Rothkopf, 1988). The results of this study may be considered for the design of text-based instruction.

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